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Wheat and Wheat Products as Human Foods, 1952

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Wheat and Wheat Products as Human Food

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Contents

Introduction

WHEAT is one of the most important cereals grown in India coming next only to rice and the great millet, *Jowar* (*Sorghum vulgare*). It is, however, the most popular cereal in the north-western parts of India and until a decade ago, its consumption was confined mainly to the northern and central parts of India. Very little of it was consumed in the peninsular portion of the country whilst elsewhere wheat was certainly considered a good enough cereal but not the most popular one for reasons more than one. Owing to Japanese invasion of Burma in 1941-42 rice imports to India from that country had been completely cut off during the World War II. As a result of shortage of rice, use of wheat in appreciable amounts as an alternate cereal had to be advocated and popularized in South India through ration shops and other distribution centres. During this period, India was receiving large consignments of wheat from North American countries and efforts, therefore, were made by different States in South India to popularize consumption of wheat by actual demonstration of cooking methods and also by opening of State-managed restaurants catering wheat dishes in certain urban areas.

Wheat is said to be as old as human civilization itself. Though wheat grains have been found in the ruins of Mohenjo-Daro in a fully developed form yet it appears that rice was the most popular cereal in ancient India. In the Sushruta Samhita almost one whole page has been devoted* to the description of different strains of rice and their nutritive qualities, whereas the virtues and properties of wheat have been disposed of within one sloka of four lines†. Even today the acreage of wheat sown in India stands next to rice and *jowar*. Nevertheless next to rice, wheat is the most-preferred cereal in the country. Within recent years the consumption of wheat has increased appreciably in India, the primary reason being that a large amount of wheat is being imported owing to an overall insufficiency of rice in the world market and the high prices prevailing for this particular cereal grain. The successive annual figures for the import of wheat into undivided India for each year from 1943 to 1947 have been reckoned at 213,087 tons, 563,018 tons, 793,552 tons, 1,183,163 tons and 655,737 tons respectively. Further there has been of late a tendency amongst a limited section of the educated middle classes to include more wheat products in their diet. Probably this attitude to wheat originates from the spread of knowledge that (a) whole wheat flour contains almost double the quantity of protein and five times the quantity of calcium as is contained in rice grains and (b) a mixture of cereals in the diet is more conducive to health than otherwise. The scientific basis for such a knowledge or belief has been dealt with later in the text.

* Sutrasthanam, Adhyaya 46, Slokas 4—18.

† Sutrasthanam, Adhyaya 46, Sloka 42.

Cultivation of Wheat

In the Northern hemisphere the sowing of wheat is mostly done from August to November or December. In temperate areas the spring wheats are sown in March-April. In the Southern hemisphere the sowing season is from April-August. The crop is harvested in one country or another all the year round as indicated below :

January	..	Australia, New Zealand, Argentina, Chili.
February	..	India.
March	..	India, Upper Egypt.
April	..	India, Persia, Asia Minor, Lower Egypt, Mexico, Cuba.
May	..	Japan, China, Central Asia, Morocco, Algeria, Tunis, Texas.
June	..	South France, Spain, Italy, Greece, Turkey, Japan, United States south of 40°.
July	..	France, Germany, Austria, Hungary, Rumania, Bulgaria, Southern Asia, Canada, Northern United States.
August	..	England, Northern France, Belgium, Holland, Central Russia, Canada, United States.
September	..	Scotland, Sweden, Norway, Canada.
October	..	Northern Russia, Finland.
November	..	South Africa, Argentina, Peru.
December	..	Burma, Australia and Argentina.

Most of the important wheat growing areas of the world are found in the temperate regions between latitudes 30°—60°N and 27°—40°S. The crop is, however, grown successfully in a number of countries in the tropics also. With regard to altitude, wheat has a wide range. It can be grown from sea level up to a height of 10,000 ft. mainly in the tropics. There are records of its growth at an altitude of 14,000-15,000 ft. in Tibet.

The growth and development of the grain of wheat are very satisfactory when a bright, dry and warm ripening period follows a cool and moist growing season. An annual rainfall of 20-30 inches is sufficient for the crop if the greater portion of it falls during the growing season. As most of these conditions are available to the agriculturists in the north-western parts of India, the yield of the crop is high in Punjab, P.E.P.S.U., Jammu and Kashmir and Uttar Pradesh, though wheat is grown in almost all the States of India. Particulars about total area sown under wheat, the total production and the yield per acre during the year 1949-50 for each of the States are shown in Table I. Relevant figures of production and average yield for some of the more important countries of the world are quoted in Table II.

TABLE I

Area, Production and Yield per acre of Wheat in India—1949-50

States	Area (000 acres)	Production (000 tons)	Yield per acre (lb)
Assam	2	1	1,120
Bihar	1,653	347	470
Bombay	2,064	348	378
Madhya Pradesh	2,591	499	431
Madras	10	1	224
Orissa	12	3	560
Punjab (I)	2,955	1,196	907
Uttar Pradesh	8,201	2,585	706
West Bengal	89	21	529
Hyderabad	384	42	245
Jammu & Kashmir	158	58	822
Madhya Bharat	2,116	328	347
Mysore	(a)	(b)	
P.E.P.S.U.	850	320	843
Rajasthan	1,085	193	398
Saurashtra	282	84	667
Travancore-Cochin	(a)	(b)	
Ajmer	31	6	434
Bhopal	502	69	308
Bilaspur	39	6	345
Coorg	—	—	—
Delhi	56	13	520
Himachal Pradesh	277	55	445
Kutch	19	5	590
Manipur	(a)	(b)	
Tripura	—	—	—
Vindhya Pradesh	738	110	334
The Andamans and Nicobar Islands.	—	—	—
Total.	24,114	6,290	584 (Average)

(a) Below 500 acres. (b) Below 500 tons.

Source—Directorate of Economics and Statistics, Government of India.

TABLE II

Area, Production and Yield per acre of Wheat in Selected Foreign Countries—1950.

Country	Area (000 acres)	Production (000 tons)	Yield* per acre. (lb)
U.S.A.	61,740	27,502	998
Canada	27,021	12,366	1,025
Australia	11,701	4,902	938
Argentina	14,085	5,413	861
Pakistan	10,715	3,958	827
France	10,673	7,579	1,591

*Calculated by dividing Col. (3) by Col. (2)

Source—Monthly Bulletin of Food and Agricultural Statistics issued by F.A.O. (September 1951).

According to the "Supplementary Report on the Marketing of Wheat in India" issued by the Directorate of Agricultural Marketing in India the estimated area under improved wheats in the country increased from 6.5 million acres in 1934-35 to 10 million acres in 1943-44, an increase of 3.5 million acres. The proportion of acreage under improved wheat to total wheat acreages during the same period has increased from 19 per cent to 29 per cent. It is a rather conservative estimate and the actual acreage under improved wheats is likely to be a figure higher than that stated above.

Within the scope of this brief memorandum, it is not possible to describe the different improved strains grown in the country and as such only a few important ones will be mentioned. Work in connection with improvement of wheat has been in progress at the Indian Agricultural Research Institute and in the States of Punjab (I), Uttar Pradesh, Bihar, Madhya Pradesh and Bombay.

A number of varieties with high yields and good grain quality has been evolved at the Indian Agricultural Research Institute of which N.P. 4, 12, 52, 80.5, 111, 125 and 165, etc., are quite popular and are being grown in large areas in different parts of the country. Besides these, certain other varieties have recently been evolved at this Institute which are tolerant to one or more of the three rusts. They are being tried at a number of stations in the important wheat growing tracts. Some of them, particularly, N.P. 710, 718, 720, 737, 758, 760, 761, 770 and 775 have been found to do quite well in certain areas. A few among these are already being multiplied on a large scale for distribution.

In the Punjab (I) C. 217, 228, 250, 253, 518 and 591 are some of the popular improved varieties. Of these C. 518 and C. 591 have given

very good yields and have maintained their reputation during the last ten years. The other wheats released later are suitable for tracts with different conditions of climate, soil, etc. In Uttar Pradesh N.P. 4, 52, 125, Kanpur 13 and C. 591 are some of the improved wheats which are very popular and are grown in large areas in western, central and eastern parts of the State. In Bihar, N.P. 52 has replaced the local wheats to a considerable extent and has been the most popular variety so far during the last ten years or more. In Madhya Pradesh, A.O. 90, A. 112 and A. 115 are some of the improved varieties grown in the State. N.P. 52 is also grown to some extent. In Bombay, some of the popular improved varieties that are being grown are N.P. 4, Niphad 4, Mondhya 417-5, and among the durums, Jaya, Vijay, Gulab, Motia, etc. In Saurashtra, N.P. 165 is now a very popular variety.

In certain areas the local wheats are cultivated mostly on account of their adaptation to surroundings or due to some special quality factors which make them preferable to consumers in the locality. In the State of Saurashtra there is local Katha wheat which is popular amongst the people for its alleged health-restoring and nutritive properties. Its flour is credited with absorbing more of ghee and hence is considered suitable for preparation of sweet dishes. In Uttar Pradesh, there is a 'Hard Kathia' variety which is grown in Bundelkhand district and tracts around Madhya Pradesh and there is a semi-hard white wheat 'Chandausi' variety which is grown in Muzaffarnagar district.

Rusts of wheat cause great destruction in all wheat-growing regions of the world. The reduction in yield of wheat due to these has been very great in India also. The great black rust epidemic during 1946-47 almost completely destroyed the wheat crop in Madhya Bharat and Peninsular India. The most effective and the least expensive method of control of the disease is to grow resistant strains of the crop. Breeding for rust resistant strains of wheat is in progress at the Indian Agricultural Research Institute, New Delhi, and its sub-station at Simla. The work is being done by certain State Agricultural Departments also, such as, in Madhya Pradesh, Bombay and Punjab (I). In New Delhi and Simla special attention is being paid to the production of strains resistant to all the three rusts and certain strains have been produced which possess a high degree of resistance separately to the different rusts. These strains are now undergoing trials at a number of stations. The more important work of synthesising wheat strains simultaneously resistant to all the three rusts has now been taken up. In Madhya Pradesh and Bombay, breeding of strains resistant to black rust only which is dominant in those areas is being carried on. In the former State, certain strains, viz., Hyb. 278, 65, 277, 12, 11-6 have recently been evolved which are very resistant to black rust. These are now being multiplied and will be released for general cultivation very shortly. In Bombay, certain strains highly resistant to black rust, viz., Kenphad yellow early, Kenphad Yellow mid-late and Kenphad red early, have just been released.

Effect of Manurial Treatment and Hybridization

THE factors which influence the quality of wheat have been studied by several workers. The main aspects which have received considerable attention are the vitamins of the B-group, the protein fractions and the mineral constituents of the grains. The application of certain manures to soil has long been known to affect the composition of wheat. Some investigators have reported that wheat which had received organic manures had more nutritive value than those which had received inorganic fertilizers. The latter, on the other hand, was found by Indian workers to be better than the crop which had received none of the treatments. Wheat grown on a soil fertilized with phosphate was also reported to be richer in vitamin B content than that grown without phosphate fertilizer. Later investigations on the Vitamin B_1 content of wheat grown with different fertilizers failed to show any significant difference in this constituent. It has also been claimed by some investigators that the location of the area cultivated had a much greater effect on thiamine content than the variety of the seed grown and that the thiamine content was correlated to the ash content. Others have reported, however, that thiamine content of wheat, and not riboflavin, is influenced by genetical factors.

Several investigators have studied the variation in the gluten and other protein fractions of wheat flour due to manurial treatments and hybridization. The variability in the protein content of wheat is also well noticed when wheat, grown over a wide range of territory exhibiting a large range of soil types and climatic conditions, are compared. The inclusion of a legume or green manure crop in the rotation has been found to increase the nitrogen content of wheat.

Studies on the quality of different improved varieties of Indian wheat and the effect of manurial treatments on their quality have recently been undertaken at the Indian Agricultural Research Institute. Phosphatic fertilizer has been observed to have increased the phosphorus content of the grains, grown in the Permanent Manurial and Rotational Experiments at Pusa (Bihar). Riboflavin content and the diastatic activity of Indian wheat have also been found to vary from variety to variety.

The wheat area mainly comprises of the black soils of Bombay, Madhya Pradesh, Hyderabad and Central India and alluvial soils of Uttar Pradesh, Bihar (Gangetic alluviam) and of Punjab (Indus alluviam). Most of the black soils area is unirrigated. Hard wheat (*Triticum durum*) is more commonly grown in black soils and bread wheat (*Triticum vulgare*) in the alluvial area.

In alluvial soils with irrigated wheat, a combination of nitrogen

and phosphate (artificials) appear to have given the best increase in yields (61 per cent over control) and is followed by combined treatment organics plus inorganics with an average increase of about 37 per cent over control. Unirrigated wheat trials are few in these soils and generally appear to respond best with a combination of organic+inorganics (average about 42 per cent over control). Generally inorganics have given low response.

In black soils, most of the trials on wheat are under rainfed conditions and a combination of inorganic N and P gave the best increase in yields. Each of the treatments inorganic N, inorganic P, oil-cakes, bulky organic manures gave approximately equal yield and an increase of 20-25 per cent over control. Irrigated trials, although few, indicate the beneficial effect of bulky organic manures in the black soils (61 per cent over control).

Average good yield of wheat crop in India removes from the soil about 50 lbs. of nitrogen, 21 lbs. P_2O_5, and 60 lbs. K_2O and 30 lbs. CaO per acre. In order to maintain and improve the yield, soils of India generally require to be treated with nitrogen and phosphorus fertilizers as shown by great majority of manurial experiments conducted throughout the country.

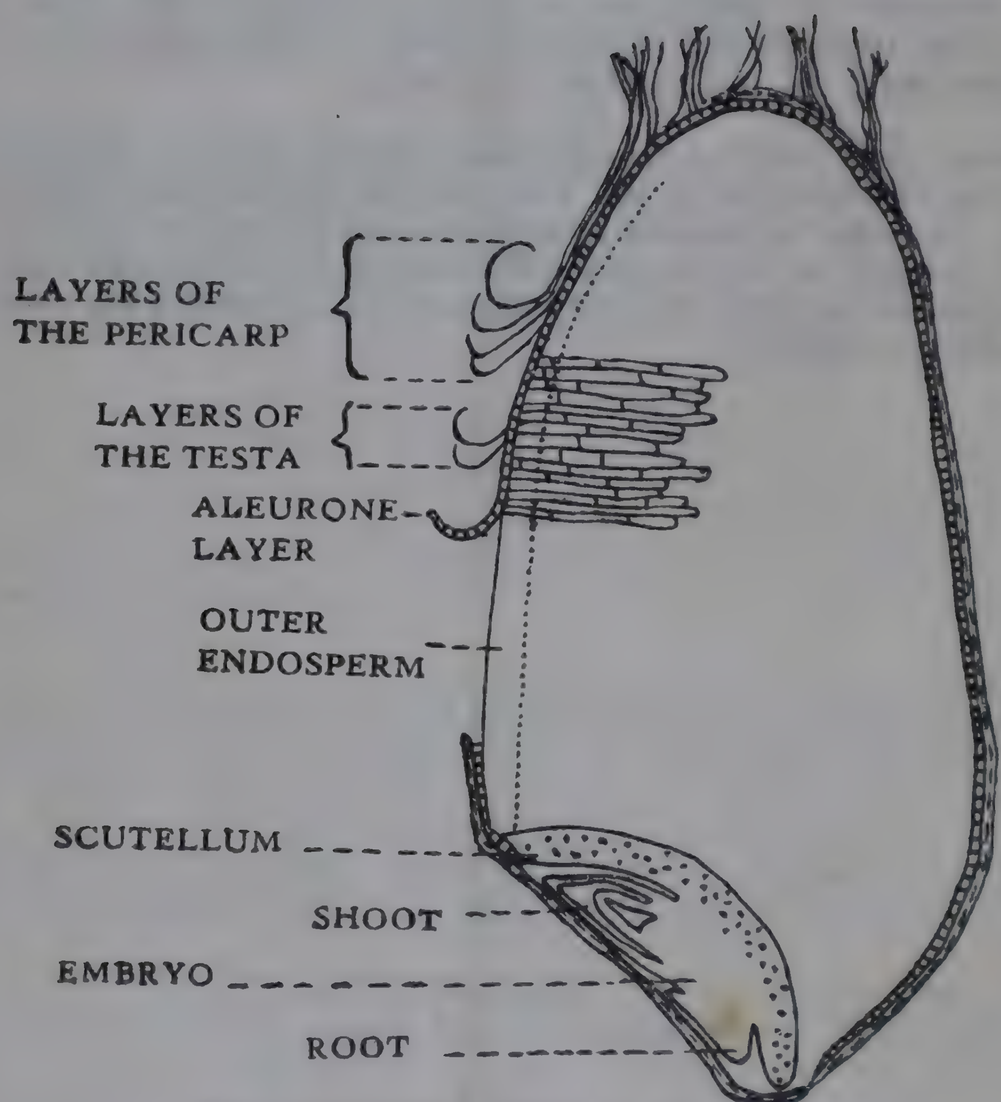

Fig. 1—Longitudinal section of wheat grain.

Structure of the Wheat Grain

THERE are innumerable strains of wheat cultivated all over the world, but the gross structure of the grain is more or less the same in all of them. The apex or the tip of the grain is commonly narrower than its base and near the apex there are a few fine hairs which can be seen on close inspection only. If a cross section of the wheat grain is taken it may appear to be slightly triangular in some of the varieties and in others it may be evenly rounded. There is a groove or linear depression on the front aspect or the *ventral* surface of the grain which extends to its entire length. The embryo or the germ is on the *dorsal* side, on the opposite side or ventral surface of the grain extending to about one third of its length and its site can be located by a shrivelled appearance of the surface at this spot. The outermost layer of the wheat berry, or caryopsis as this grain is known botanically, contains layers of pericarp, under which lie the layers of the testa (see Fig. 1). Testa is of interest as it is the colour bearing layer whilst pericarp appears to be relatively transluscent. These two layers together form a thick covering to protect as it were the edible portion of the grain within and slightly overlaps the germ. Next to testa is a layer of cells which can often be distinguished from the central core by its colour and it is known as the aleurone layer which may account for as much as three per cent of the total weight of the grain. The wheat bran should botanically consist of the outer layers up to and excluding the aleurone which is actually a part of the endosperm. Contiguous to the aleurone is the kernel of the grain which supplies the bulk of the wheat flour. The colour of the wheat kernel or the edible portion of wheat varies from light buff or yellow to reddish brown. Though the aleurone layer and the kernel constitute the endosperm of the grain yet the former has a tougher structure and during milling it remains firmly attached to the bran. The outer layers of the endosperm, which includes the aleurone, are not as mealy as the inner endosperm tissue. At the base of the grain can be seen the embryo with its root pointing to the bottom and the shoot rising obliquely upwards. The whole of the embryo is separated from the endosperm by a tough layer known as the scutellum. These different layers have individually grown in importance recently owing to further advances in our knowledge that the nutrients in the wheat are distributed differentially in the bran, the aleurone, the rest of the endosperm and the germ which includes the embryo and the scutellum.

Chemical Composition

WHEAT, like every other food grain, is not invariable in composition. The food value or the nutritive quality of any sample of wheat depends on strains, growing and harvesting season, the technique of cultivation as also the quality of the soil and the climate of the locality in which it is grown. In addition to such variations, detailed studies on the food values of the edible portion of wheat, have indicated a significant difference in nutrient composition between different parts of the grain. A good deal of useful and informative work on the nutritive value of the different components of wheat grains, has been carried out during the early forties at the Cereal Research Station, St. Albans in England. Consequently, it will be extremely fallacious and misleading to ascribe an "average" figure for nutrient composition of edible portion of wheat grain or whole wheat flour. It is desirable that in future compilation of the table of food values, the result of analysis of the component parts of wheat be shown separately and anything like an overall average nutritive value for the edible portion of the wheat grain be regarded as a thing of the past. The following tables (Table III and Table IV) based on the results of the investigation at St. Albans and compiled by Professor R. A. McCance and Dr. (Miss) E. M. Widdowson in one of their joint papers in the Proceedings of the Nutrition Society (Vol. 4, page 2) are reproduced below :

TABLE III

Component parts of the wheat grain as percentage of the whole.

Component part	Percentage by weight of whole wheat
Bran, including aleurone layer	12.3
Endosperm excluding outer layers	83.0
Outer layer	2.0
Germ, embryo	1.2
Scutellum	1.5
Whole grain	100.0

TABLE IV

Composition of whole wheat grain, the endosperm and the germ.

Constituent	Whole wheat	Endosperm		Germ	
		Central portions	Outer layers	Embryo	Scutellum
Protein %	8·9	8·1	14·6	33	29
Fat %	2·2	0·7	...	15	30
Carbohydrate %	66·8	75·8	...	...	...
Phosphorus mg/100 g.	213	59	1017	1160	1900
Phytate phosphorus mg/100 g.	311	8	874	400	1300
Iron mg/100 g.	3·0	0·5	12	9	...
Vitamin B_1 I.U. per g.	1·6	0·1	1·8	3·00	60
Riboflavin ug/g	1·5	0·4	1·8	15	...
Nicotinic acid ug/g	42	5·0	184	60	...

It will be noticed in Table IV that protein percentage of the whole wheat has been shown as 8.9, a rather low figure, but the fact should not be forgotten that English wheat is known to be low in protein content. Indian wheat on the other hand contains, very often, a higher percentage of protein. During the early forties extensive investigations, on the protein content of wheat grown in different parts of India, were carried out and the results of these investigations have been tabulated and shown in Table V.

It will be seen that in Punjab (I), protein content in 70 per cent of the samples ranged between 9 and 11 per cent. In Madhya Pradesh and Bombay, however, though the figures for average yield are below the average figure for the whole country (Table I), yet these two States have recorded comparatively higher protein content.

Nutritive value of the different components should not, however, be considered as absolute. It is needless to mention that moisture and the proximate principles vary to a certain extent even in each of the component parts. In order to bring out this variability more clearly the range of variability and the typical figures for average value in wheat flour of 75 per cent extraction for each of the more important parts of the grain has been shown in Table VI, which has been quoted from "The Nations Food" edited by Bacharach and Rendle and published by the Society of Chemical Industry.

TABLE V

Percentage incidence of protein in the samples of wheat obtained from some of the Indian States
[*All figures of protein* (= $N \times 5.7$) *recalculated on an uniform moisture basis of* 13.5%]

Protein range	Punjab*		Uttar Pradesh		Bihar		Madhya Pradesh		Bombay	
	Number of samples	Percentage	Number of samples	Percentage	Number of samples	Percentage	Number of samples	Percentage	No. of Samples	Percentage
Below 7·0	1	0·07	12	0·7	...	...	...	...	...	...
7·0-7·9	16	1·09	148	8·97	20	4·1	9	1·01	...	...
8·0-8·9	199	13·50	449	27·2	79	16·1	96	10·8	10	2·3
9·0-9·9	587	39·9	586	35·5	207	42·2	249	28·01	64	14·8
10·0-10·9	445	30·2	308	18·7	153	31·2	270	30·4	90	20·8
11·0-11·9	152	10·3	107	6·5	25	5·1	187	21·03	93	21·5
12·0-12·9	59	4·01	31	1·9	7	1·4	56	6·3	89	20·6
13·0 and above	14	0·95	9	0·6	...	...	22 †	2·5	87 ‡	20·1
Total	1,473	100·0	1,650	100·1	491	100·1	889	100·1	433	100·1

* Includes produce from Punjab (P)

† More than 15% in one sample

‡ More than 16% in two samples

TABLE VI

Composition of White flour, bran and germ.

	White flour (endosperm)		**Bran**		**Germ**	
	Range Per cent	Typical figure (75 per cent ext.) Per cent	Range Per cent	Typical figure Per cent	Range Per cent	Typical figure Per cent
Moisture content	12-16	13·8	10-15·5	12·5	10-14	13·5
Oil	1-1·5	1·2	3-5·4	4·7	6-11	10·8
Protein (N × 5·7)	6·2-14·1	12·0	11·8-17·3	15·0	17·2-27·4	25·9
Ash	0·32-0·55	0·55	4·2-7·6	4·65	4·0-5·0	4·1
Fibre	0·2 or less	0·2	7·5-11·0	7·9	1·8-4·3	1·9
Carbohydrates		72·25		55·25		43·8

It will be seen that there is a large difference in ash content between that of endosperm and of bran. As a matter of fact the ash determination is usually employed as a measure of the degree to which bran powder is present in the flour. Wheat bran has ordinarily an ash content of about 5 per cent while that of endosperm free from bran, varied from 0.25 to 0.30 per cent. The aleurone layer alone accounts for the greater part of 5 per cent ash in the bran and the pericarp layers which are more fibrous are comparatively poorer in ash. The ash content of flour is also useful as a rough indication of its vitamin B_1 and mineral contents.

If one must draw up a list of mineral constituents of whole wheat the names of about two dozen elements have to be enumerated, but the grain is not rich in any such of the entities which are nutritionally important. White flour (or *maida*) is more deficient in these elements than whole meal flour (or *atta*) or flour of intermediate extraction. It is said that because a large amount of wheat flour is consumed every day in areas where wheat is the staple food, even the small amount of iron present in wheat, makes an appreciable contribution to the daily requirement of the individual. The amount of calcium, the other mineral of importance in human nutrition, present in whole wheat has been found to vary between 22.0 mg./100 g. to 98.0 mg./100 g. and the average has been worked out as 51.4 mg. per 100 g. of wheat. Per 100 g. of white flour the amount present may be as little as 10 mg. It must be remembered in this connexion, however, that availability of calcium in all cereal depends to a considerable extent upon the amount of phytic acid present in the total phosphorus content. Table VII below indicates the amount of calcium, iron and phytate phosphorus present in straight run wheat flour of varying extractions :

TABLE VII

Calcium, iron and phosphorus content of flours of different extractions.

Straight run flour	Total Ca. mg/100g	Total Fe. mg/100g	Total P. mg/100g	Phytate P. as per cent of total P.
70 per cent,	18·7	1·0	31·9	31·0
75 ,, ,,	19·0	1·0	41·2	36·2
80 ,, ,,	22·0	1·7	77·3	49·8
85 ,, ,,	25·7	2·5	113·3	57·6

As in the case of calcium and phosphorus, figures for protein content of whole wheat vary in different layers of the grain. On the whole it may be stated the concentration of protein gets less and less as the percentage extraction of the 85 per cent flour is lowered.

Distribution of fat (or oil) in the different components of wheat grain may be seen in Tables IV and V.

Unsaponifiable matter consisting of sterols or higher alcohols is present to the extent of approximately 5 per cent in fat from all fractions of the wheat grain except the bran. One characteristic feature of the fat or oil present in wheat is its high percentage of unsaturated acids like linoleic and linolenic. It may be stated in this connexion that unsaturated fatty acids have been proved to be essential in the growth and production of rats but its utility in human nutrition has yet to be established.

Concentration of the different Vitamin B complexes in the wheat grain has been given in Table IV. It has been reported that wheat grains contain no appreciable amount of Vitamin A and that they lack completely Vitamin D. At one time it was thought that the carotenoid pigment, which is fairly evenly distributed throughout the wheat grain, is a Vitamin A precursor but that belief has been disproved by chromatographic analysis. The pigment for the most part consists of anthophyll which is a plant colouring matter. Ungerminated wheat grain contains very little or no Vitamin C. The distribution of Vitamin E in wheat has been studied and it has been proved that this vitamin is by no means solely confined to the germ but is also present in the endosperm. It has been stated that even 70 per cent extraction wheat flour contains an appreciable proportion of Vitamin E. The total content of this vitamin is of the order of 3.5 mg. per 100 g. Recent investigations have shown that wheat germ is a good source of folic acid.

Milling of Wheat

SINCE the time wheat has been grown as a food grain by man, efforts have been made to separate the fibrous matter in the wheat including its branny covering from the mealy endosperm for pulverization and consumption. Ordinarily, the outer layers of the wheat berry are more difficult to pulverise than the inner endosperm. From the earliest times two pieces of stones of different shapes and sizes have been used for grinding the grain and obtaining the flour separate from the bran particles as far as possible. Certain amount of bran separation, however, was and is still being done by sieving and through bolting or use of the proper types of sieves flour or meals of different degrees of refinement could be obtained. Probably it was the Arabs who contrived to harness for the first time the natural elements like wind and flowing currents of water for grinding of wheat flour on a bigger scale. Gradually the practice was improved upon and spread to Europe and other parts of the world. With the advent of machine age the Roller Process flour mills were evolved and developed. Such mills were and still are propelled either by steam power or electrical energy. The motive behind the progressive development of flour mill machinery can be ascribed to the growing tendency for replacement of human labour by machines and also to the consumers' demand for a highly refined flour which could easily be baked as fine loaf. The flour produced with the help of ordinary grinding stones either propelled manually or by wind or flowing water was not of a standard quality and was often coarse.

In the roller mills, disintegration of wheat grains is carried out in successive stages by means of grooved steel or chilled iron rollers operated by steam or electrical power. In the ordinary type of grinders irrespective of whether they are manually rotated or power propelled, the making of flour from wheat is completed in one operation whereas in the roller type of mills it is done in four or five stages. During each stage of crushing the grain is broken and reduced to a smaller size each time the 'break stock' and "break flour" are sieved out in different grades for further treatment in the rollers. The separated pieces of bran are blown out from intermediate products by a strong blast of air. Fine flour* (*maida*), coarser flour (*atta*) and semolina (*suji*) are thus separated during the various breaking stages. Prior to the second world war the mills in the United Kingdom turned out flour of 70 per cent extraction. Consequently such a flour consisted mostly of the internal endosperm and was free from bran as also from embryo, scutellum and the outer endosperm, in other words the three components which were particularly rich in nutritious material. Recent researches have indicated

* Strictly speaking the term 'flour' should imply the product obtained by systematic and maximum separation of the bran from endosperm, and the term 'meal' should imply a pulverization product of the wheat grain. But the word flour is very loosely used and ordinarily stands for both the products. It is in the latter sense that the word 'flour' has been used in the text.

that aleurone layer in particular possesses some desirable nutrients and its rejection in milling is singularly unfortunate. But aleurone layer firmly adheres to the fibrous structures of the wheat and is thus removed with the bran. Consequently a clean separation of the grain at the level of the aleurone layer, so that it could be included within the flour, and the bran left completely out, would have been a very desirable procedure from the nutritional standpoint. The second world war precipitated this urge in most of the countries of the world and the rate of extraction in the United Kingdom was raised from 70 per cent to 73 per cent in October, 1939, to 75 per cent in April, 1941 and subsequently to 85 per cent in March 1942 and again reduced. At the request of the Government the millers agreed to adjust their milling process in such a way that more and more of outer endosperm and the germ could be included and at the same time the bran kept out. Intensive researches on milling processes were also carried out and ultimately the 85 per cent extraction flour known as National Wheatmeal in the United Kingdom satisfied reasonably well the bakers and consumers.

The germ has a high nutritive value but its inclusion in the flour is not liked by many because it imparts a colour to the flour and makes the flour less stable for storage and is said to have an adverse effect on the baking quality. Similarly bran also imparts a strong flavour to baked flour which is not popular with many persons. Unfortunately the dietary inclinations and food habits all over the world are very rarely guided by cold logic of science. Considerable amount of research has also been carried out to determine the optimum moisture content in the wheat grains which will allow of milling of a flour of the desired baking quality. In passing, it may be observed that the moisture content of the grain determines to a certain extent the degree of toughness of the bran. In quite a large number of milling establishments in Europe and America the wheat grains are conditioned as to their moisture content before they are subjected to milling. It is said that the conditioning or tempering of wheat grains prior to its treatment in the flour mills results in a gain of about 1 to 2 per cent of weight increase in the total flour produced. Here the miller probably gains a little in weight.

It is said that milling of flour by roller type mills was introduced in India for the first time in 1880 by importing the required machinery from the United Kingdom. Since then the number of mills have increased considerably with imported machinery from Germany also. Sometime ago a computation was made and it was found that there were altogether 79 flour mills in India of which the distribution was as follows :

Punjab (I)	10
Delhi	3
Uttar Pradesh	18
West Bengal	15
Bihar	3
Orissa	3
Madras	5
Bombay	12
Other States	10

Concentration of flour mills in Punjab and Uttar Pradesh where wheat is the staple food of the majority of the people can easily be understood, but the existence of a number of flour mills in and around Bombay and Calcutta might require some explanation. One of the reasons seems to be that in both these cities, which are cosmopolitan in their character, quite a large number of people consume wheat regularly. Besides, there is a fair percentage of population who like baked loaf in these cities and which can only be prepared out of milled wheat flour. Another possible reason, though unbelievable in the present circumstances, seems to be that until about fifteen years ago, wheat flour and wheat products were exported from these two ports to countries abroad. Table VIII has been copied from the Food Statistics of India published by the Department of Food, Government of India in 1946 and it gives the amount of different types of wheat products manufactured in the flour mills in undivided India for a period of five years.

TABLE VIII

Quantity of Different Types of Wheat Product milled in undivided India from 1939-1944.

(Figures in thousand maunds)

Year	Flour (Maida)	Atta (High grade)	Atta (Low grade)	Bran	Suji (Samolina)	Others	Total
1939-40	6678	3300	2716	2852	692	73	16311
1940-41	7087	3428	2758	2825	663	139	16900
1941-42	7077	4491	3031	2973	482	123	18177
1942-43	4551	4020	2707	1767	288	59	13392
1943-44	3389	7421	1866	1545	344	41	14606

According to this statement the total quantity of the various products handled works out as under :

Flour	36 per cent
Atta (high grade)	29 ,, ,,
Atta (low grade)	16 ,, ,,
Bran	15 ,, ,,
Sooji	3 ,, ,,
Others	1 ,, ,,
Total	100 ,, ,,

It may be of interest to mention here in this connexion that 100 units of wheat ground in a roller mill will ordinarily yield 34 units of *atta*, 41 units of *maida*, 8 units of *suji* and 17 units of bran.

Before electrically driven roller mills had been introduced, all the wheat flour or wheat meal consumed in this country was being produced by various types of stone grinders. The crudest type of grinders consist of a pair of circular stones, one resting over the other and operated by hand, a device commonly known as *chakki* (चक्की). The stone grinders may not always be manually operated but driven by a pair of bullocks performing circular movement and this contraption often seen in Punjab villages, is known as *Kharas* (खरास). A *chakki* or stone mill may also be driven by water from a flowing stream, mostly in foot-hill areas, when it is known as *gharat* (घराट). With the introduction of electricity, power driven *chakki* or stone mills have also come into operation. All these types of grinders exist even today. In bigger cities services of professional grinders were available but with the gradual mechanization of the milling process this particular profession is becoming obsolete. The services of the professional grinders which could be obtained in lieu of a comparatively small fee, included washing of wheat after hand picking of extraneous matter, drying the grains in the sun and finally pulverizing them in *chakkis*.

With the advent of oil engines and electricity a number of the small grinding units or power driven *chakkis* were established mainly in cities and bigger towns. The Indian consumer ordinarily prefers flour prepared in these power driven *chakkis* or grinders to the finished product from mills. Both in the power driven and manually operated *chakkis* flour of 90 to 95 per cent extraction is ordinarily produced. There is no conditioning of the grain (adjustment of moisture contents) as is done in the other mills though wheat grains are cleaned and washed before being sent to grinders and housewife sifts or bolts the flour to the necessary consistency, before use. This practice is wasteful but in the absence of facilities for purchase of good quality of wheat flour, the ordinary consumer prefers the *chakki* product. On the other hand production of *maida*, fine flour and *suji* which have a good demand in the Indian market is possible only in power driven roller mills.

In the flour mills, particularly in the western countries, the flour is bleached chemically either by powder or gas in order to produce very white flour even from wheat with slightly coloured kernel. The consumers and consequently bakers insist on such type of flours which will allow of loaf being baked as white as possible. Further, for improving baking qualities 'improvers' such as acid calcium phosphate, persulphates of ammonium and potassium and potassium bromate are used. Bleaching agents include Beta gas which is nothing other than chlorine gas containing 0.5 per cent of nitrosyl chloride, nitrogen peroxide and benzyl peroxide. Researches published by Sir Edward Mellanby about three years ago have proved that agene containing nitrogen trichloride which had been very popular with millers for more than 30 years as an improver and bleaching agent, can cause hysteria in dogs. As result of this discovery use of this particular bleaching agent ordinarily applied at the rate of ½ to 2 g. per 100 lbs. of flour is being given up. Further investigations carried out in the United Kingdom and in the United States of America have shown that the toxic effects are produced by some alteration in the gluten of the flour by agene. Toxic effects, however, are not peculiar to

gluten alone, but can be produced in other proteins if treated with nitrogen trichloride. The trichloride gets itself linked to a particular polypeptide grouping and the toxic agent can withstand even enzymic hydrolysis. Within the last five years reports published on both the sides of the Atlantic indicate that of all the animals tested dog is the most susceptible to agenised flour. Human feeding trials have not so far shown any harmful effects, but it is quite possible that ill effects may take a very long time to become apparent or they may be so insidious as to escape detection. The fact should, however, not be forgotten that the striking ill effects shown in animals by agenised flour cannot be regarded with complacency. Until much longer human feeding trials are undertaken one must look with suspicion on flours bleached with nitrogen chloride, particularly in a country where, in wheat eating areas, flour may contribute as much as eighty per cent of total calories in the diet. In U.S.A. chlorine dioxide is being used instead of agene. It has been claimed that this particular improver and bleaching agent is as good as agene with the added advantage of not being toxic to dogs and other animals. The important researches carried out at the British Cereals Research Station at St. Albans within the recent years indicated that Vitamin B is highly concentrated in certain part of the germ, and further researches in milling technology showed that this particular section of wheat can be segregated during milling in such a manner as to ensure that the greater part of it passes into flour. In support of the Morris Milling Process, patented in 1935, it has been claimed that the pulverized germ present in the finished flour is rendered nonrancid by aeration. In the process the wheat stocks during all the stages of milling are aerated by means of a low vacuum draft system. Another important observation was that a part of the endosperm adjoining the bran is not only rich in protein but also in iron and nicotinic acid. As a result of these experiments along with those on milling technology it was possible to lower the extraction rate in the United Kingdom from 85 to 82.5 per cent, whilst retaining in the resultant flour all essential nutrients in adequate proportion. This flour known as the National Flour in the United Kingdom, has been in use there during the recent years.

In Europe and America wheat flour is mainly used for baking and the value of a particular flour for this purpose depends mainly on the amount of proteins present and the properties of the gluten which is formed from wheat proteins when wetted with water. Standard experimental baking tests have been devised for bread, biscuits, cakes and other pastries. In India, however, wheat is mostly eaten in the form of unleavened *chapatis* made from *atta* or pulverized whole wheat meal as distinct from the milled wheat flour of Western countries. A small percentage of wheat, however, is consumed as baked loaves, biscuits, buns and pastries.

In discussing the technology of milling of wheat flour, a passing reference may be made to the Australian Rycena or a wheat product which can be cooked and eaten like rice. "It was thought that this product might help in solving the dilemma of mal-distribution of cereal products. It does not, however, appear to have been widely consumed by rice eating population. Wheat (preferably of low gluten content) is hydrolysed at 180°F, which destroys the active physical properties of the gluten in the endosperm of the grain.

This operation also enhances the palatability of the products and does not impair the food value of the gluten. The chemical agent used has not been revealed. In a subsequent technical phase of the process, the hydrolysed wheat is stripped of part of the layers which constitute the bran. Simultaneously, both ends of the grain are removed to open up at one end channels in the grain, while the germ at the other end is removed. The removal of the outer layer permits quicker and better penetration of the moisture when the cereal is cooked or steamed. Removal of the germ end eliminates spoilage of the products through rancidity." It is said that the finished Rycena looks more like a grain of barley than a grain of rice and it cooks somewhat more slowly than rice.

Quality Standards for Wheat Flour

QUALITY standards for wheat flour can very conveniently be discussed under two heads : (a) physico-chemical characteristics and (b) baking qualities.

(a) Physico-chemical characteristics

No quality standards for wheat flour, ordinarily sold in the market for civilian consumption, have so far been prescribed in India. One of the reasons for such a state of affairs may be ascribed to the fact that total consumption of wheat per caput is much less than the corresponding figures for Western countries. Further in view of the fact that the average figures of individual consumption in each of the States differ very greatly and there are millions of families in India who do not consume wheat or wheat products as a staple article of food, no average figures for consumption can be calculated for the whole of India. Table IX indicates the estimated per caput consumption of wheat per annum in some of the States in India for the years 1933-35 and 1941-43.

TABLE IX

Estimated per Capita Consumption of Wheat in some of the States in India

State	Per capita consumption during 1933-34 & 1934-35 (in lb.)	Per capita consumption during 1941-42 & 1942-43 (in lb.)	+ Increase — Decrease (lb.)
Punjab	210	205	—5
Uttar Pradesh	103	90	—13
Madhya Pradesh	67	45	—22
Bombay	57	28	—29
Bihar	29	33	+4
Bengal	12	4	—8
Delhi	254	117	—137
Rajasthan	65	56	—9
Madhya Bharat	72	40	—32
Hyderabad	19	16	—3
Mysore	6	5	—1

Source—Supplement to the Report on the Marketing of Wheat in India, published by the Agricultural Marketing Directorate, Government of India, 1946.

It will be observed that during the second world war there was an all round decrease in per caput consumption as compared to the pre-war figures. Various reasons have been advocated for the decrease and they are : increase in population, decrease in total out-turn in some of the States, increasing demand for wheat by the army and a ban on inter-State movement of wheat. It will be noticed also that Bihar figures show slight rise from 1929-33, this rise has been caused by the fact that Orissa, a non wheat eating area, was separated from Bihar during the year 1936.

Under the Food Adulteration Acts of most of the State Governments, rules have been framed fixing the limits of ash content and in some of the States the minimum gluten content. The Public Analyst is expected, however, to make a microscopical examination of the flour in order to detect the presence of starch grains other than those derived from wheat. Adulteration of atta with flour derived from other cereal grains or from pulses has become quite common, within the last 10 years. The army authorities have, however, laid down certain specifications for whole wheat, *atta*, flour (*maida*), samolina (*suji*) and bran. Relevant extract from the A.S.C. (Army Supply Corps) specification are detailed below :

(a) *Indian Wheat*—The wheat shall be sound, sweet and clean, i.e., it shall be free from unpleasant smell and discolouration and shall conform to the standards prescribed for moisture, foreign grains, insect infestation, fungus infection, dirt and other impurities. The moisture content shall not exceed the 10 per cent limit during monsoon period, and only 9 per cent during other parts of the year. Not more than 2 per cent of dirt, 4 per cent of foodgrains other than wheat, 4 per cent of touched grains, 1 per cent of damaged grains and 2 per cent of shrivelled grains are permissible in the supplies of wheat grains purchased. As regards the maximum percentage of infested grains, presence of 4 per cent of such grains are permissible from the month of December to April or May only before new crops are available. Infested grains should be completely absent in stocks purchased from May to July. For the rest of the year the limit permissible is 1 per cent during August, 2 per cent during September and October and 3 per cent during November.

(b) *Atta*—The *atta* shall be prepared from wheat which conforms to the A.S.C. specification, given in sub-para (a) above, or from imported wheat acceptable to the milling agents. The grains shall have been effectively cleaned prior to milling and *atta* shall be produced by roller mill process. When *atta* is produced simultaneously with flour, the divide will range between *atta* 70 to 55 per cent, bran 10 to 15 per cent and flour 20 to 30 per cent. When *atta* and bran are only produced a straight run *atta* between 90 to 95 per cent extraction may be produced. The *atta* shall be of characteristic taste and smell and in all respects fit for human consumption, and shall be free from insect infestation, fungus infection, dirt and other impurities. The *atta* shall be dressed through a cover of not less than 32 meshes per linear inch and shall have a moisture content not exceeding 125 per cent, gluten (dry) content of not less than 8 per cent and an acidity of not more than 0.3 per cent. In the event of *atta* being milled from imported wheat, the upper limit of permissible moisture content may be raised to 13 per cent.

(c) *Flour*—The flour shall be prepared from wheat which conforms to the A.S.C. specification quoted already or from imported wheat which is acceptable to milling agents. The wheat shall be effectively cleaned prior to milling and milled by the roller mill process. The flour shall not be artificially bleached. It shall be of characteristic taste and smell and in all respects fit for human consumption and shall be free from insect infestation, fungus infection, dirt and other impurities. The moisture content shall not exceed 12 per cent, Gluten (dry) content shall not be less than 8 per cent, acidity shall not exceed 0.35 per cent. The permissible limits of ash content in flour up to 20 per cent extraction shall not exceed 0.45 per cent, up to 30 per cent extraction not exceeding 0.5 per cent, up to 40 per cent extraction not exceeding 0.55 per cent, up to 70 per cent extraction not exceeding 0.6 per cent and in flour up to 75 per cent extraction the permissible limit of ash content is 0.7 per cent. Further the granularity percentage dressing through a **10XX**, shall be a hundred per cent. Granularity may be tested by sieving of known quantity of flour for two minutes on a hand-sieve of the correct aperture.

(d) *Suji*—The suji shall be the purified middlings obtained from milling of wheat which conforms to the A.S.C. specification stated earlier in the text. The *suji* shall not be artificially bleached. It shall be free from bran, flour, other offals, insect infestation, fungus infection, dirt and other impurities and shall have characteristic taste and smell, and be in all respects fit for human consumption. The moisture content in Suji shall not exceed 12.5 per cent, and the maximum limit of ash content is 1.5 per cent. Granularity will be such that it will pass through a No. 20 sieve but not more than 15 per cent will pass through a No. 30 sieve.

(e) *Bran*—The bran shall be prepared from cleaned wheat according to the A.S.C. specification and shall be the by-product of the manufacture of flour and/or *atta* or roller mill process. The bran shall be flaked, freshly milled, dry and sweet (without musty odour or sourness), free from lumps, dirt and husks of foreign grains or any other impurity. The bran shall not be infested with fungi or insects. The maximum limit of moisture content is 12 per cent, barley husk content is 25 per cent and weatings pollard (fine product) is 10 per cent. The fine products, e.g., weatings or pollard will be determined by a sieve, the mesh of which is similar to that prescribed for dressing *atta*.

(b) Baking Quality

In Western countries the major part of wheat products is consumed in the form of loaf and consequently the bakers' demand determines to a very great extent the type or quality of flour produced in the mills. On account of diverse types of milling or grinding practices followed in this country, the quality of flour produced, and ordinarily consumed, is far from being uniform. No report, on quality standards for wheat flour, can, however, be complete without a reference to the baking qualities of the flour. Baking qualities depend to a certain extent on the power of water absorption when it is made into dough. The water absorption, again, is influenced by the degree of fineness or coarseness of the flour. It

may be worth while to mention, in this connexion, that granulation studies of wheat flour, produced by the different types of grinding, were made in India during the forties. Percentage of the flour that passed through a 50 G.G. Sieve having 50 meshes per linear inch was considered as the criterion for measuring fineness. It was found that flour produced by *gharat* water driven stone mill produced the finest flour as 93.7 per cent of the same passed through the above sieve; and that produced by the power driven roller mill was the coarsest as only 62.7 per cent passed through the sieve. The respective figures of fineness for flour produced by *kharas* or bullock driven stone mills and power driven *chakkis* were 88.8 and 87.6 per cent respectively. Flour ground by hand driven *chakkis* had a fineness as high as 76.9 per cent. Results of investigation on *chapati* making qualities of the flours, prepared in various ways, carried out in this connexion, are shown in **Table X**.

TABLE X

Chapati making quality of wheat flour prepared by different methods

Grinding machine	Granulation in terms of "fines"	Water absorption of atta	Dough behaviour after one hour's rest	Chapati characteristics				
				Weight in fresh state	Colour	Texture	Taste	Behaviour in chewing
	Per cent	Per cent		gm.				
Gharat	93·7	75·2	Very good	65	Whitest of all	Soft and silky to touch elastic	Good sweetish	Slightly rubbery feeling
Kharas	88·8	72·8	Good	66	White	Slightly less soft and less silky to touch, less elastic.	Do.	Normal
Power-driven Chakki	87·6	72·0	Good, next to Kharas	66	Do.	Do	Do.	Do.
Hand Chakki	76·9	72·0	Do.	65	Do.	Less soft and silky to touch, less elastic	Do.	Do.
Laboratory roller mill	65·3	71·2	Fair	63	Fairly white	Coarser to touch and less elastic	Do.	Do.
Modern roller mill	62·7	68·0	Rather fair	65	Do.	Slightly coarse to touch, and less elastic	Do.	Do.

Note—Chapatis were prepared in each case from 75 gm. of dough.

It will be seen that flour from water driven mill (*gharat*) absorbs the highest amount of water for being kneaded into dough, and roller-mill flour the least. Also it will be seen that *gharat* flour made the best *chapati*. They were smooth, flexible and perfectly white in colour and further they were reported to have better keeping qualities than others. "Next in order of merit in this respect were *chapatis* made from flour obtained from *Kharas*, power driven stone mill and hand *chakki*." No difference could, however, be made out in the taste of chapatis made from the differently ground flours.

As a part of these intensive investigations attempts were made to find out if loaf and *chapati* could be baked out of a mixture of wheat flour with flour from other cereals and pulses. Table XI indicates the optimum portion of the grains other than wheat which could be mixed without affecting the table quality and acceptability of the resulting loaf and *chapati*.

TABLE XI

Maximum percentage of extraneous flour that could be mixed with wheat flour in the preparation of loaf and chapati of acceptable quality.

Grain	For baked loaf %	For chapati %
Barley (Hordeum vulgare)	10 to 15	15 to 25 (depending upon the proportion of bran removed)
Bajra (Pennisetum typhoideum)	10	15
Juar (Sorghum vulgare)	7 to 10 (depending on colour of grain)	15
Maize white	10	25
Maize (yellow)	7	20
Rice	5	Not determined
Bengal gram (Cicer arietinum)	5 to 7	Do.
Black gram (Phaseolus mungo)	5 (with good baking quality wheats only)	Do.
Mung (Phaseolus auren)	5	Do.

Source—Progress Report of the Scheme for Wheat Milling and Baking Tests, etc. Government Printing, Punjab, 1943.

These studies were carried out not so much with the view to investigate whether the millets or pulses could replace wheat during periods of food shortage but to find out whether the nutritive quality of the common baked loaf could be increased by such a mixture without, in any way, detracting from the commercial value or the acceptable quality of the loaf. Investigations were also carried out with a mixture of wheat flour with sweet potato flour, prepared from unscalded tubers and tubers scalded for two minutes in boiling water and subsequently dried, in the preparation of *chapati* as well as baked loaf. It was found that with the incorporation of 10 per cent of sweet potato flour dough became rather tough though manageable but with the incorporation of 30 to 40 per cent there was a tendency towards production of holes during flattening. If the proportion of sweet potato flour exceeded 60 per cent the dough was unmanageable and difficult to bake; both cracks and holes appeared in the *chapati* and there was a tendency to the *chapati* becoming soggy. With the increase in the introduction of sweet potato mixture the sweetness in *chapati* increased.

The loaf making quality of such a mixture was also tested and it was found that according to the standards of 'baking quality tests' of the American Association of Cereal Chemists the volume of 100 per cent wheat flour loaf was 405. With 1 per cent mixture of sweet potato the character of the loaf was slightly tough without any noticeable change in volume but with increase of the adulterant tuber flour to 5 per cent the crumb had a grey colour beyond tolerance and it was more tough but resilient. A 10 per cent mixture decreased the volume to 386 c.c. whereas 2.5 per cent mixture had actually increased the volume of loaf baked. In some Punjab wheats the volume ranged from 535 c.c. to 420 c.c. The bread (baked loaf) making quality of wheat and groundnut mixture was also tested and the two following Tables (XII & XIII) would show the details. It will be seen that wheat-groundnut flour mixture showed slightly superior baking qualities as compared to sweet potato-wheat flour mixture. The sensation of sand under teeth recorded in Table XIII is presumably due to presence of grit in the groundnut cake.

TABLE XII

Bread (baked loaf) making quality of wheat-groundnut cake mixture

Proportions in the mixture		Water absorption of flour	Loaf characteristics					
Cake	Wheat		Crust	Crumb	Texture	Grain No.	Volume c.c.	Quality score
Per cent	Per cent	Per cent						
0	100	88	Brown	Creamy white	Slightly tough	4	460	56·0
5	95	88	-do-	Greyish white	-do-	4	520	63·0
10	90	88	-do-	Whitish grey (intolerable)	Increased toughness	3 (under-developed)	475	51·5
15	85	88	Darkish brown	Increased grey	Soggy	2-3 (under developed)	445	39·5
25	75	88	Dirty brown	-do-	More soggy	(Un-developed	405	28·5
50	50	88	-do-	Dirty grey	Miserably soggy	-do-	300	15·0

TABLE XIII

Results of chapati-making tests on wheat-groundnut cake mixture

Proportions in the mixture		Chapati weight in fresh state*	Chapati characteristics				
			Colour	Texture	Taste	General remark	Dough behaviour
Cake	Wheat						
Per cent	Per cent	gm					
0	100	66	Creamy white	Slightly tough	Sweetish	Susceptibility to charring on the hot plate increases with increasing additions of cake	Good
5	95	65	Greyish white	-do-	-do-	-do-	Fair
10	90	65	Intolerably grey	Soft and silky to touch	Lacks in pure wheat taste	-do-	Decreased extensibility
20	80	65	Clear greyish red	-do-	Flat, insipid clear taste of groundnut cake, and also sensation of sand under the teeth	-do-	-do-
30	70	65	-do-	-do-	Increased insipidness and sensation of sand under the teeth	-do-	-do-
50	50	65	Reddish grey	-do-	-do-	-do-	Lifeless dough
70	30	65	-do-	-do-	Bitterness of taste appears in addition to above	-do-	-do-

* Chapatis were prepared from 75 gms. dough in each case.

Source—Schemes for Wheat Milling and Baking Tests, etc. Government Printing, Punjab, 1946.

The climatic conditions prevalent in certain parts of India affect adversely the keeping qualities of the wheat flour ordinarily consumed in the country. Naked eye examination of flour is often sufficient to detect the presence of weevils and foreign matter which may often render the flour of doubtful value as human food. On storing wheat flour for some length of time a certain amount of acidity and rancidity may also develop which can be detected by smell and organoleptic tests. Samples of wheat flour showing these characteristics in a pronounced manner should not be used as human food. It is not uncommon to find various adulterants mixed with wheat flour by unscrupulous dealers.

Wheat flour and wheat are both difficult to store for any considerable period of time in homes. Largely owing to the practice of consuming wheat flour or wheat meal in the form of *chapati,* an average house-wife in wheat eating areas of India handles and stores proportionately larger quantities of wheat flour than is done by her sisters in western countries. A good deal of spoilage of wheat and wheat flour occurs in this country at the wholesale and retail stores and in homes. No accurate determination of the percentage of spoilage based on the total production and import of wheat grains in this country has been so far made. Opinions have at times been expressed that about 5 per cent of total grains harvested from the fields are destroyed through infestations of rodents and insect pests. The Director of Storage in the Ministry of Food and Agriculture, Government of India, has very kindly drawn up a short note on the "Storage of Wheat" which is attached at the end of the report as Appendix A. A copy of another note on "Insect pests of wheat and its method of storage" issued by army authorities is also attached as Appendix B.

Nutritive Value of Wheat Flour

The chemical composition of wheat has already been described but as a hundred per cent wheat meal is not ordinarily consumed, the original nutrients present in the grains are lost to a certain extent during the process of milling. It has already been stated in the earlier part of the text, that the more precious nutrients in wheat are present in the outer layers and during the process of milling it happens to be that these outer layers are shed mostly with the bran. Apart from the carbohydrate, protein is one of the important nutritional constituents of wheat flour. The biological value, or usefulness in the human physiology, of wheat protein, as a matter of fact of any other protein, depends to a very large extent on its amino acid make-up. Table XIV indicates the approximate amino acid content of wheat and wheat flour and has been quoted from Nutrition Abstracts and Reviews, Volume XVI, No. II, pp. 257-261, October, 1946.

TABLE XIV

Approximate Amino Acid Content of Wheat
(in grammes per 16.0 of nitrogen)

	Whole wheat (g)	Wheat gluten (g)	Wheat grm. (g)
Arginine	4·2	3·9	6·0
Histidine	2·1	2·2	2·5
Lysine	2·7	2·0	5·5
Tyrosine	4·4	3·8	3·8
Tryptophane	1·2	1·0	1·0
Phenylalanine	5·7	5·5	4·2
Cystine	1·8	1·9	0·8
Methionine	2·5	1·5	—
Threonine	3·3	2·7	3·8
Leucine	6·8	7·5	6·7
Isoleucine	3·6	3·7	—
Valine	4·5	4·2	—
Glycine	—	7·2	

It will be seen that the amount of lysine, an important amino acid is low as compared to the proteins of milk, meat, eggs and pulses. It has been noticed by some observers in India (unpublished results) that during infestation of wheat flour with weevil the protein or more precisely the gluten content is considerably reduced and

often such flours barely contain 3 to 4 per cent of gluten instead of the usual 8 to 10 per cent. Contrary to a belief which persisted till about a decade ago, the quality of wheat protein is actually inferior to that of rice protein. This lack in quality, however, is more than made up by the larger quantities of proteins present in wheat flour. It is within the bounds of possibility that there exists a supplementary effect between proteins of the endosperm and that of the bran. It has been established that the nutritive value of whole wheat protein is higher both in proteins sparing and growth promoting effects than those of white flour. An experiment was conducted in France a few years ago in which the experimental subjects consisted of two men and two women and they lived on bread prepared from wheat flours of 70 to 85 per cent extraction and from wheat meal of hundred per cent extraction. These feeding trials were continued for about a month and the average values for the percentages of Nitrogen ingested were 84, 87 and 72 respectively. "The authors* concluded that bread made from whole wheat flour, in spite of the superiority of its nutritive value to that of wheat flour in respect of the quantity and quality of its protein, phosphorus, calcium and Vitamin B_1 content, loses its advantage in practice owing to the lower amounts of these constituents absorbed. The content of essential nutrients in the bread made from flour of 85 to 86 per cent extraction was not inferior to that of whole wheat bread, while digestibility of these was not less than observed with white bread." The carbohydrate present in wheat flour is mostly in the shape of starch and very little of sugar is present unless fermentation sets in. The loss of thiamine, if wheat is milled to *maida*, is very great as also the Vitamin B_2 content. Table XV which has been quoted from Nutrition Abstracts and Reviews, Volume VIII, No. 1, pp. 560, January, 1939, gives the loss in thiamine content due to milling process.

TABLE XV

Vitamin B_1 contents of Wheat and Wheat Flour

Material			International Units of Vitamin B_1 per g.
Whole wheat			1.2 to 3.4 (mean 1.86)
Stone ground flour			1.6
Flour	94	per cent extraction	1·2
,,	82	,, ,, ,,	1·0
,,	75	,, ,, ,,	0·4
,,	70	,, ,, ,,	0·37
,,	60	,, ,, ,,	0·24
,,	42	,, ,, ,,	0·00

* Quoted from an unpublished document on wheat compiled by the Nutrition Division of the F.A.O.

It is commonly believed in this country that the range of temperature developed in the wheat during pulverization and in the resultant flour by various processes, affects to a certain extent nutritive values of these flours. It is thought that the higher the temperature developed during the process of grinding the lower the nutritive value. Investigations, carried out in India in March 1944, have shown that the highest rise of temperature is with power-driven *chakki* and the least with hand driven *chakki*. A result of the investigation has been tabulated and shown in Table XVI.

TABLE XVI

Particulars about the different wheat grinding machines and the temperature of the resultant flour.

Grinding machine	Temperature (in F°) of			Approximate weight of the upper grinding stone	Approximate revolutions per minute of the upper grinding stone.	Approximate output of flour per hour	
	Room	Flour at the spout	Bagged flour				
				Mds.		Mds.	Srs.
Power-driven *chakki*	82.4	131.0	131.0	7	250	10	0
Kharas	81.0	95.5	90.0	5	47	0	26
Hand-driven *chakki*	79.0	79.0	82.0	0.4	73	0	3
Gharat	74.0	91.5	85.0	6	118	0	37
Modern roller mill	75.0	86.0	86.0	*	450	6	20
Milling and Baking Laboratory (roller)	82.0	88.0	85.0	...	@	...	

* Grinding stones run vertically in this and are comparatively light in weight.

@ Grinding is done in this machine between two steel horizontal rolls, moving at different speeds, the faster one at 900 R.P.M. and the slower at 380-485 R.P.M.

Source—Progress Report of the Schemes for Wheat Milling and Baking Test and appointment of (an Assistant) Cereal Technologist for Wheat Work in India for the year ending 30th June, 1944 and printed by the Government of Punjab, 1945.

It will be seen from the table that in flour ground with hand-driven *chakki* there is hardly any rise in temperature, and in the product from the roller mills also the rise in temperature is comparatively low, presumably owing to the cooling device provided in the modern milling machinery. Concentration of thiamine and nicotinic acid was estimated in the flour produced with some of these devices. It was found that

wheat ground into flour with power-driven *chakki* suffered the highest loss of thiamine content; the loss could be as much as half or 50 per cent of the original quantity present. Flour produced by hand *chakki* and *gharat* suffered a loss of 19 per cent and 13.5 respectively, but roller mill product on the contrary showed a gain of about 24 per cent. Without going into explanations for such a finding, it would be relevant to point out that the product from the roller mill is 'flour' in the truest sense of the term and therefore a selective product, whereas the other products are wheat meals. The loss suffered in Nicotinic Acid content is still higher as would be seen in Table XVII.

TABLE XVII

Thiamine and Nicotinic Acid Content of Flours.

Material	Thiamine (B_1) Actual Ug/g	Thiamine (B_1) Loss Suffered over parent wheat, per cent.	Nicotinic acid Actual Ug/g	Nicotinic acid Loss suffered over parent wheat, per cent.
Patent flour	3·7	...	33·0	...
Roller-mill flour	4·6	24·3 (gain)	23·0	30·3
Gharat flour	3·2	13·5	16·6	49·7
Hand-driven *chakki* flour	3·0	29·0	14·7	55·5
Power-driven	2·7	27·1	16·7	50·6
Chakki flour	1·7	54·0	15·0	54·5

Source—Scheme for Wheat Milling and Baking Tests, etc. Government Press, Punjab, 1946.

An attempt was made by these workers to find out if spreading out the flour in thin layer soon after its pulverization by the power-driven *chakki*, in order to ensure rapid cooling, did in any way help in cutting down the loss in vitamins. Unfortunately the results were not conclusive and they could not be pursued any further.

The differential distribution of B vitamins, calcium and iron in the products of wheat milling has been studied in detail in the United States of America. Table XVIII is quoted from the circular "Nutritive Values of Wheat with Reference to Techniques of Preparation in the United States" issued by the Office of Foreign Agricultural Relations of the U.S. Department of Agriculture, dated 15th January, 1948.

TABLE XVIII

The Distribution of B Vitamins, Calcium and Iron in the Products of Wheat Milling.

Product	Thiamine 1* Mill yield	Thiamine 1* Micro-grams per gram	Thiamine 1* Percent of total in mill fraction	Riboflavin 2* Micro-grams per gram	Riboflavin 2* Percent of total in mill fraction	Niacin 3* Micro-grams per gram	Niacin 3* Percent of total in mill fraction
	Pct.		Pct.		Pct		Pct.
Patent flour	63·0	0·68	8·0	0·34	20·5	12	10·2
First-clear flour	7·0	3·00	3·9	0·62	3·2	66	3·2
Second-clear flour	4·5	12·37	10·0	1·85	7·7	83	4·7
Red-dog flour	4·0	29·66	22·0	3·80	14·1	120	7·6
Germ	0·2	22·93	0·9	...	...	68	0·2
Shorts	12·3	17·40	39·6	2·80	32·5	159	17·8
Bran	9·0	9·37	15·6	2·80	22·0	330	56·3
Wheat	100·0	5·03	100·0	1·00	100·0	70	100·0

	Pantothenic acid 4* Micrograms per gram	Pantothenic acid 4* Percent of total in mill fraction	Pyridoxine 4* Micrograms per gram	Pyridoxine 4* Percent of total in mill fraction
Patent flour	5·7	43	2·2	48
First-clear flour	9·6	72	3·9	85
Second-clear flour	12·8	96	5·7	...
Wheat germ	15·3	...	9·6	...
Wheat	13·3	...	4·6	...

	Calcium 5* Mill yield	Calcium 5* Calcium (as Ca)	Calcium 5* Calcium in ash (as Ca0)
	Pct.	Pct.	Pct.
Patent flour	58·0	0·018	5·2
Clear flour	12·0	0·023	3·9
Low-grade flour	2·6	0·038	3·6
Middlings, total mill run	14·4	0·112	3·4
Bran	13·0	0·116	2·4
Germ	7*	0·069	1·9
Wheat	100·0	0·045	2·8

Product	Iron as (Fe) 6* micrograms per gram	Iron in ash
		Pct.
Patent flour	8·4	0·18
First-clear flour	17·4	0·22
Second-clear flour	38·7	0·26
Red-dog	96·2	0·30
Shorts	139·0	0·28
Bran	146·2	0·21
Germ	91·3	0·19
Wheat	41·6	0·23

* 1. Sherwood, R. C., Nordgren, R., and Andrews, J. S. *Thiamin in the Products of Wheat Milling and in Bread.* Cereal Chem. 18, 811 (1941).

* 2. Andrews, J. S., Boyd, H. M., and Terry, D. E. *Riboflavin Content of Cereal Grains and Bread and its Distribution in Products of Wheat Milling.* Cereal Chem. 19, 55 (1942).

* 3. Andrews, J. S., Boyd, H. M., and Gortner, W. A. *Nicotinic Acid Content of Cereals and Cereal Products.* Ind. Eng. Chem. Anal. Ed. 14, 663 (1942).

* 4. Tepley, L. S., Strong, F. M., and Elvehjem, C. A. *The Distribution of Nicotinic Acids in Foods.* Jo. Nutrition 24, 167 (1942).

* 5. Sullivan, B. and Near, C. *The Ash of Hard Spring Wheat and its Products.* Ind. Eng. Chem. 19, 498 (1927).

* 6. Andrews, J. S. and Felt, C. *The Iron Content of Cereals.* Cereal Chem. 18, 819 (1941).

* 7. Germ diverted into middlings; analyses are for sample of germ from same mill run.

The Aleurone layer has a very high nutritive value but unfortunately most of it is lost during milling even with the improved methods. It has been proved that white flour or *maida* has a higher digestibility value than the coarse flour or *atta* of 85 to 90 per cent extraction. Bran has a digestibility of only 45 per cent or less but its inclusion in the flour is favoured by many for its laxative properties. It is, however, still a matter of opinion if wheat bran as roughage in the diet is to be preferred to the type of indigestible fibre obtained from leafy vegetables such as cabbage, *palak, lal sag,* etc. There is an opinion that the roughage obtained from leafy vegetables when properly cooked leave soft residues after digestion due to soaking of water and hence are less likely to irritate the soft lining of bowel than comparatively harder wheat bran which does not soften with water. Wheat flour contains both pantothenic acid and pyridoxine in appreciable amounts even though about half of the content present in the original wheat grain is lost during milling processes. Incidentally, it may be mentioned here that owing to our lack of knowledge as to the actual requirement of both these components of Vitamin B complex, it is not possible to state whether they are present in nutritionally adequate quantities in the flour of different degrees of extraction.

The mineral content of wheat flour is low as is that of other cereals generally. But wheat flour is richer in mineral element than rice and *atta* is richer than *maida*. In other words, the ash content of the flour increases with higher extractions. The ash of the flour, as also of the whole wheat consists mainly of potassium phosphate. Calcium is present in fair proportion but in view of the presence of phytin phosphorus much, if not most, of this important mineral is neutralized and passes out unabsorbed through the faecal matter. All cereals excepting oats are poor in fat and wheat meal contains only two per cent but the wheat fat, particularly wheat germ oil contains Vitamin E.

It will be seen from the above that the calcium content of wheat flour is an uncertain factor and does not indicate the quantity that may be absorbed by the human organism. Further, the total amount of calcium ordinarily ingested through this particular item of food is much below the accepted requirement of (0.68 g.) the individual. It has been estimated that for a man to meet his total requirements of calcium he will have to eat daily 4¼ lbs. of flour or 6¼ lbs. of baked loaf. Consequently attempts have been made within the recent years to compensate against the lack of this essential nutrient in wheat flour by addition of extraneous calcium in the form of powdered chalk. This aspect of the question has been referred to, later in the text.

Human Feeding Trials with Rice and Wheat Diets

Any information on the nutritive value of wheat flour would be incomplete unless it includes a discussion on the qualities of typical Indian diet based on wheat. The relative merits of typical rice and wheat diets in India have been investigated by metabolism studies on human subjects. These studies included an estimation of the daily intake and output of nutrients like protein, calcium, phosphorus, iron, copper and manganese in order to determine whether adequate amounts of these nutrients were being supplied by the typical diets. The composition of rice and wheat diets given to the experimental subjects were as follows :

Rice Diet*	Grammes	Wheat Diet	Grammes
Rice	550-600	Wheat	500-550
Pulses	60	Pulses	70-90
Fish	70	Vegetables	200
Vegetables	200	Sugar	50
Mustard Oil	30	Ghee	30

* Subjects on vegetarian diet were given 30 grammes of extra pulses in lieu of fish.

The daily protein intake with rice and *atta* diets varied between 76 and 82 gm. and on both these diets the human subjects were in positive protein balance and retained considerable amounts of nitrogen. The digestibility and biological value of the mixed proteins of the rice diet were 80 and 60 respectively while the corresponding values for wheat diet proteins were 90 and 59. Thus it may be seen, the biological values of mixed proteins of both rice and wheat diets were found to be very nearly similar and the digestibility of wheat diet proteins was definitely better. It could be safely concluded from these experiments, that the typical rice and wheat diets of India containing about 18 oz. of cereals per day and which were fed to the subjects were quite adequate with regard to the protein requirements of human adults. With smaller amounts of cereals, however, in the absence of adequate protein supplements, the position would be quite different. The Indian rice and wheat diets were also found to be adequate with regard to their phosphorus content.

The story, however, was quite different with regard to the calcium content of typical Indian diets. Calcium, it may be remembered, is one of the most important constituents of bones. Both the rice and

atta diets were found to be very low in calcium. On both these experimental diets, the subjects under observation were almost always found in negative calcium balance. In other words, they excreted more calcium than the amount of calcium they received through their food. The deficit was found to be more with rice diets than in the case of wheat diets. One of the greatest defects of typical Indian diets is insufficiency of calcium and also of vitamins. The deficiency of calcium and many other defects in the diets can be made up by the incorporation of 10 ozs. of milk in the diet per day. But milk is in short supply in India and is also beyond the purchasing power of the average Indian. Incorporation of about 100-200 g. of leaves of pumpkin (cucurbita pepo) or 200-300 g. of cabbage, lady's finger, or drumstick or leafy sag camaranth, spinach, etc. in the daily diet is likely to bring back an adult from the negative to a positive calcium balance.

The calcium content of pumpkin leaves is very high, ranging between 240-300 mg. per 100 g. of the leaf is edible and can be included in poor wheat or rice diets. Lime taken with betel leaves leads to increased absorption of calcium and even bones of small fish taken whole, also supply considerable amounts of calcium and brings the individual in positive calcium balance.

Iron which is a constituent of the haemoglobin is contained in adequate amounts in rice and atta diets, provided undermilled rice or whole wheat is consumed. A small amount of copper is also needed for helping the conversion of absorbed iron into haemoglobin of blood. Manganese, though required in small amounts, is also an essential element from the standpoint of nutrition. Typical Indian wheat diets supply adequate amounts of both these elements : copper and manganese.

One of the serious defects of both the rice and the wheat diets in India is the deficiency of several vitamins which can be made up by the provision of adequate amounts of milk which is not feasible at present. Fresh green vegetables contain carotene and their intake in sufficient amounts can supply the needs of Vitamin A and also to some extent of Vitamin C which, however, exists in abundance in citrus fruits like oranges, lemons and also in amla and guava. Partial replacement of rice by *atta*, and intake of under-milled rice, preferably parboiled, is likely to meet the requirements of B group of vitamins. The wheat diets are better in these respects as compared to diet based on rice as the main cereal; with *jowar* and *bajra* as the cereal in diet the Vitamin B complex can be of the same level as in wheat diet. With plenty of sunshine in this country, the needs for Vitamin D for adults is not great. Infants and growing children in whom bone development is going on rapidly require supplies of Vitamin D in the form of egg yolk, milk fat or fish liver oils (like cod or halibut) or the synthetic vitamin.

Although typical wheat diets in India are in general superior in nutritive value to rice diets normally consumed in the country, there is ample scope for improving the former by diminishing the quantity of wheat in favour of increased intake of protective foods, such as milk dairy products, fresh fruits, vegetables and eggs. In view of the apparently higher nutrient content of wheat flour as compared to

other cereals, quite a number of medical men particularly in Bengal, have from time to time strongly advocated the inclusion of substantial amount of wheat in rice eaters diet. A reference had already been made, earlier in the text to the gradually increasing consumption of wheat in India. Beginning from the food scarcity years, i.e. since 1943 onwards attempts have been made in this country to replace part of the rice or wheat ration with other cereals. Some people have disliked or resented the partial substitution of their ration with unfamiliar grains. Opinions were expressed in the lay press against the use of wheat flour adulterated with the flour of other cereals. Whenever a suspicion or doubt is cast against the nutritive value of this or any other type of cereal, people are apt to forget that the nutritive quality of the diet of any individual, family, community group or any section of population, is not ordinarily determined by the nutrient constituent of the cereal quota of the food alone, but it depends to an appreciable, if not to a very great extent, on the other constituents of diet as well. This is as much true of wheat diet as of diets based on any other cereal.

A reference may also be made to the human feeding trial that was carried out in this country some years ago to determine the biological value of proteins in a mixed cereal diet. Six healthy adult males served as experimental subjects in the investigation. The non-cereal quota of the experimental diet consisted of pulses 75 g. to 90 g., butter fat (*ghee*) 35 g. to 45 g., potatoes 100 g. to 120 g., bottle gourd or vegetable marrow 140 g. to 150 g. and leafy vegetables 125 g. to 150 g. The proportion of cereal quota to the other items of the non-cereal quota in the diet was kept constant throughout the feeding period. But the varying range of figures shown for each of the dishes was due to the fact, that not all the subjects were eating the same quantity of food but every one was having whatever amount he wanted. During the first period of the experimental feeding the cereal quota consisted of rice alone and in the successive experimental periods the cereals consisted of either rice and wheat or of rice, wheat and barley or rice, wheat and maize or rice, wheat and *cholam* (*jowar*) or rice, wheat and *ragi* (*marooa*) or finally rice, wheat and *bajra*. The proportion of wheat to the millets was 3 : 1, in other words the flour used for the preparation of *chapati* given to the subjects consisted of 75 per cent by weight of wheat flour and 25 per cent any cereal flour other than wheat and rice. At the termination of the experiment the observers had recorded the following biological values :

Rice only	66.6 per cent
Rice and wheat	55.1 ,, ,,
Rice, wheat and barley	59.8 ,, ,,
Rice, wheat and maize	56.8 ,, ,,
Rice, wheat and *cholam* (*jowar*) ..	54.1 ,, ,,
Rice, wheat and *ragi*	60.2 ,, ,,
Rice, wheat and *bajra*	57.4 ,, ,,

The digestibility co-efficients of mixed proteins in all the six types of experimental diets did not differ from one another materially. Whilst still on the subject of digestibility, a reference may be made to an experiment carried out at Cambridge during the second World War in which six scientists had volunteered themselves as subjects.

It was found that the average co-efficients of apparent digestibility of nitrogen in bread made from flours of 100 per cent and 73 per cent extraction were 85.5 and 91.0 respectively. This finding on human beings more or less confirmed the results of two sets of rat experiments carried out at the Lister Institute, London, with whole wheat meal and flours of 75 and 85 per cent extraction. Summarising both the human and rat experiments referred to, it has been very rightly suggested that "This loss of about 6 per cent in digestibility was, however, more than compensated by the greater nutritive value of the proteins of the wheat meal."

Nutrients in Loaf and Chapati

For baking of loaf or cooking of *chapati* (चपाती the name used for the unleavened bread so widely consumed in India) wheat flour is the most popular ingredient all over. Loaf or *chapati* can also be prepared from the flour of barley, millets or maize but not with rice flour or oat flour. But wheat flour has certain unique properties which make it the flour of choice. The proteins of wheat flour gluten and gliadin when soaked in water form an elastic paste which holds, on and permits of a considerable amount of stretching. The dexterity of Indian housewives in rolling the dough, without breaking, into very thin layers with a common rolling pin and pastry board, is to be seen to be believed. Further the gluten in wheat flour can allow the dough to be baked into the texture of sponge by putting carbon dioxide either in the shape of a jead or baking powder within it. In *chapati* also the dough is blown up and gluten is coagulated on the surface but more so in the loaf. This is the reason why *chapati*, loaf or cakes and pastry, made of wheat flour is very light in weight as compared to those made of any other flour. The controversy of brown bread versus white bread is a very old one and no useful purpose will be served by recounting the various arguments advanced by the admirers on either side. The controversy has been kept alive because some of the arguments are based on prejudice or acceptance of unproven assertions. A short resume, however, of the facts leading to the controversy may be of some interest here.

Dr. Sylvester Graham of 'Graham Bread' fame started a campaign more than a century ago to popularise brown bread believing that the bran in bread was of assistance in digestion. Due to economic and other reasons, however, large sections of the people in several parts of the world, before the industrial revolution were habituated to bread made of brown flour. With the invention of roller mills and urbanization of labour, white bread gained in popular appeal. It was not only pleasing in appearance and taste but the keeping quality was better than that made of whole meal. It has already been stated that in order to obtain white flour by milling processes the outer integuments of the grain are lost as human food resulting in the diminution of certain nutrients. Bearing in mind that the composition of the flour does depend to some extent on the degree of extraction, inherent genetic variation of the seeds, and soil on which it is grown it can be said that the whole meal is richer in several nutrients than white flour. The bran and pericarp, however, are said to be of some value to habitually constipated individuals as roughage in the diet. The bran is rich in phosphorus which is present as phosphate esters of inositol ('Phytin Phosphorus') and also as phospholipids and other compounds. This is not a very important point in favour of whole wheat bread because phosphates can be obtained from many other articles of diet commonly consumed by the people. The proteins of bran are partly utilized and in the amounts that are ordinarily

consumed, it is apparent that proteins from this source contribute but little to the daily requirements of man.

In spite of the eulogies made about the virtues of whole meal bread, if the public was free to choose the kind of loaf they desired the choice would probably lie with white bread. It would be interesting to recall the Swiss propaganda about a decade ago in respect of brown bread. Between the years 1936-37 the millers in Switzerland had to produce brown flour (85 per cent extraction). Because of the intensive drive launched by the State to popularise brown flour and the subsidy given to the mills towards this end, a cheaper bread of brown flour resulted and the percentage of consumers rose to 75 per cent of the total population. When the subsidy was removed and the consumption of brown flour fell in spite of the continued propaganda for whole bread the percentage of consumers was hardly 10 per cent, a figure which was not far from the normal consumption of this kind of flour in the country. In this connexion one cannot fail to notice an amusing contradiction in choice exhibited by wheat eaters. It has already been stated how people would ordinarily prefer white bread to brown bread, as far as baked loaves are concerned. But with *chapatis* the choice appears to be in the reverse direction. Very few, if at all, of the habitual consumers of *chapati* would prefer this article of food prepared from *maida* or white flour. Every *chapati* eater knows that, unless made of *atta* or brown flour *chapatis* can never be so sweet.

It is unfortunate that in spite of the widely prevalent use of *chapati* in India very little of the nutritive qualities of this popular article of diet have been scientifically investigated. In comparison to the tremendous volume of literature available on the different aspects of baked loaf as human food the work pertaining to *chapati*, is negligible.

Practical nutrition is concerned not so much with the nutrient contents of individual foods but with nutritive value of diets consumed as such. But unfortunately in a poor country like India most part of the dish consists of cereal grains and therefore the food value of this particular preparation, *chapati* assumes slightly greater importance than usual. Nutritive qualities of wheat flour have already been described at some length. The point at issue is that since in cooking or baking of bread the dough is subjected to heat and consequently what is the loss in nutrients thereby. During baking the dough is subjected to prolonged heat whereas in the cooking of *chapatis* the exposure to fierce heat is direct though for a much shorter period. Ordinarily most proteins show a decrease in nutritive value when subjected to heat, especially under conditions which lead to dehydration as it happens in the case of *chapatis*. No doubt the intensity of the heat determines the degree of the loss in the qualities of protein. It has been shown that toasting, and exploding or puffing of bread reduces the biological value of proteins, though probably amino-acid content undergoes no appreciable change. The effect of the difference in the intensity of heat has been very clearly demonstrated by the fact that in rat feeding experiments the crust of white bread was found to have lower biological value than the soft crumb inside. As much as 13 per cent decrease in the biological value has been noted.

Probably the steaming of the dough does not affect adversely the protein so much as baking. In baking of bread made of milled wheat flour, from 9 to 14 per cent loss to the extent 9 to 14 per cent in thiamine content has been observed, whereas with samples of *chakki* or stone ground whole meal, a loss of 33-35 per cent on the original thiamine content has been recorded. Toasting of white bread has been found to give rise to no loss in thiamine, whereas others have recorded a loss of about 9-31 per cent if the toasting is continued for about a minute. It, therefore, follows that in the case of *chapati* which is subjected to intense heat right inside the oven the resulting loss on the outer surface may be much greater. As far as starch content of the wheat is concerned if baking of either loaf or *chapati* is done after a certain amount of fermentation of the dough starch may be partly converted into maltose and sugar. Probably during baking there is very little loss of riboflavin or lysine. There is a possibility that concentration of both these vitamins may be increased as a result of baking.

A reference has been made to lack of lysine in wheat flour. Milk contains a fair amount of lysine. Consequently *chapati* soaked in milk forms a very good diet and the biological value of protein is increased. The preparation of *Missi chapati* where the dough is prepared with added milk is a very healthy practice.

Fortification of Wheat Flour

It would, therefore, appear reasonable to conclude then, that though whole meal loaves contain higher amounts of certain nutrients than white bread, the disadvantages are (1) poor preference as determined by taste, (2) low digestibility (the bran in certain individuals might act as an irritant), and (3) poor keeping quality.

If the diet is varied and the quantity of bread eaten is small it is of no great consequence, whether white or brown loaf is eaten. In the lower economic groups of wheat eaters, wheat forms the bulk of the diet, and it is precisely in this class of people that one has to ensure that physiologically adequate nutrition requirements are met with. If the choice of the people is on white bread, they should have it, but it should be realized that it is possible to restore the nutrients which are lost in the milling process by adding the synthetically produced vitamins and some minerals.

There are several terms which have gained popular usage: 'Fortification,' 'Enrichment' and 'Restoration' of foodstuffs. Strictly speaking restoration is the term used for adding the elements lost in processing the food, to the extent that they would be present in the original food. The terms fortification and enrichment are synonymous. By these terms are meant addition of the elements lost in the refining process of food beyond the extent to which they were originally present, and also it might be that nutrients not originally present in the food may be added. Iodization of salt is a classical example of fortification. In regions where endemic goitre is prevalent, it is now an accepted practice to add iodides to common salt distributed to the region. This is a very efficient and convenient way of dealing with a nutritional deficiency. The justification advanced for fortification of bread is that in the milling of wheat certain nutrients are lost and these are made good by fortification.

The fortification of milled wheat flour gained an impetus during the war years. It was considered necessary in the U.K. to fortify the flour with the synthetic Vitamin B_1 at the rate of 0.20 grammes per sack of 280 lbs. In January, 1941, the Food Ministry of the U.K. introduced the 'National Wheat Meal' or 85 per cent extraction flour; in spite of vigorous propaganda however the voluntary response from the people was not very appreciable. When this flour was made compulsory in 1942 an appeal was made to the public that this measure was to conserve shipping space. At the earliest opportunity the extraction rate specification was lowered to 82½ per cent and then to 80 per cent. Meanwhile, the pioneer work of Hinton revealed the distribution of Vitamin B_1 in high concentration in the 'scutellum' of the grain. The millers later refined their technique and it was found possible to mill to such a degree that the flour was practically white and pleasing in appearance but contained the scutellum. This is about 80 per cent

extraction. At this time addition of calcium to flours of high extraction was considered necessary in view of the results of experiments conducted by McCance and Widdowson. These workers carried out balance experiments on 10 human subjects over a period of nine months. Wheat flour of extraction varying from 69 per cent to 92 per cent was used in the diet. Calcium carbonate was used for fortifying. McCance and Widdowson found that unfortified brown bread depressed the absorption of calcium. The more one ate the worse his calcium balance was likely to become. If phytic acid in the brown bread was the main cause for lowered assimilation of calcium, the addition of just enough calcium to inactive phytic acid would result in a bread that could be described as neutral and the calcium balance in an individual would not be affected by consuming this bread. If more than adequate amount of calcium to precipitate all the phytate were to be added, the bread would supply calcium available for absorption and balances are likely to improve as consumption rises. The phytate content of white bread is so little that the unfortified material is probably fairly neutral and any degree of fortification would probably make the bread a source of available calcium. Consequently national wheat meal was fortified by the addition of extraneous calcium carbonate at the rate of 14 oz. of this mineral per 280 lbs. sack. The wheat flour ration consumed by the armed forces in India is fortified with 7 oz. of calcium carbonate per 280 lbs. weight of wheat flour. Regarding iron in bread, these workers observe that in spite of the large amounts of iron in whole meal, bread made from it may not be as good a source of iron as is generally supposed.

What was found necessary as an emergency measure during the war has by experience been shown to be a sound practice in the matter of fortification of wheat flour, and has been followed up in the post-war years in the U.K. Several types of fortified foodstuffs are in use in the U.S.A. for several years. As a matter of fact, the pendulum has swung to the extreme in that country where enterprising commercial organizations sell carbonated beverages fortified with vitamins.

The fortification of wheat flour will be a sound practice as will be evident on the following considerations :

(i) White flour can be used for bread making which is widely acceptable and liked by the people and the bran can be utilized for cattle feeding and other purposes.

(ii) There is no need for a comprehensive campaign, extolling the virtues of brown bread, which never has been and perhaps never will be popular with the consumer public.

(iii) The millers are not asked to scrap their existing milling equipment.

(iv) The synthetic vitamins perform the same physiological functions in the body as the vitamins from 'Natural' products. Hence the addition of synthetic vitamins and minerals to the desired level in wheat is physiologically sound.

(v) The cost of production of synthetic vitamins that are now used for fortification in other countries is cheap. It has been estimated that basic annual cost of eradicating beri

beri in the Orient is not greatly in excess of 10 cents per capita. (Kik and Williams, Bull. of N.R.C., 1945, Washington, D.C.) These workers have also said that it will be necessary to produce the necessary vitamins in at least the larger Asiatic countries to avoid unpopular drains on their foreign exchange.

(vi) The fortification must be carried out on such foodstuffs which reach the widest section of the population and are consumed throughout the year, in the case under discussion—wheat flour.

(vii) The fortified product should be indistinguishable from the substance before fortification as regards appearance, colour, smell and the most important of all—taste.

(viii) The added substance must be physiologically and chemically compatible with other nutrients, natural or added, supplied by the food.

(ix) Fortification should make available a nutrient of which the people or large communities are short.

(x) The substances and the amounts added must be clearly labelled because the public has a right to know what they are buying and consuming.

During pre-war years in the United States of America many administrators and other groups, concerned with the welfare of the nation, had been discussing the feasibility of enriching wheat flour and bread as a positive approach to safeguard health and well-being of the nation through better diets since the latter part of the thirties. The Food and Nutrition Board of the National Research Council and the Council on Foods of the American Medical Association had also supported this movement. Subsequently, the National Nutrition Conference called by President Roosevelt in 1941 endorsed the suggestions and actual enrichment of flour with iron, thiamine and niacin began to be effective in 1941 and riboflavin was added to the list in October 1943. At the beginning, the enrichment of flour and bread was on a voluntary basis but in about two years time when the enrichment of white bread and rolls was made mandatory by War Food Order about three-fourths of all family flour and bakers' white bread were being enriched. It has been estimated that during the years 1943-45 about two-thirds of the total flour consumed in the United States was enriched. In October 1946, the War Food Order requiring enrichment of bread and rolls expired, but the cult of enriched flour had created such an impression in that country that no less than 21 States and the territories of Puerto Rico and Hawaii had enacted legislation requiring enrichment of bread and flour. In the rest of the States, it is reported, that voluntary enrichment is being continued. The enrichment standards for bread have been adopted for the four substances shown in Table XIX.

TABLE XIX

ENRICHMENT STANDARDS PREVALENT IN U.S.A.

(Milligrams per pound unless otherwise stated)

Required	Flour Standard		Bread Standard	
	Min.	Max.	Min.	Max.
Thiamine	2.0	2.5	1.1	1.8
Riboflavin	1.2	1.5	0.7	1.6
Niacin	16.0	20.00	10.0	15.0
Iron	13.0	16.0	8.0	12.5
Optional				
Calcium	500	1500	300	800
Vitamin D (U.S.P. Units)	250	1000	150	750

(From a note prepared by the Committee on Cereals, Food and Nutrition Board, N.R.C., Washington, D.C., October 1944).

APPENDIX A

Short note on Storage of Wheat

(By Shri K. R. Sontakay, Director of Storage, Ministry of Food and Agriculture, Government of India)

Wheat is a commodity which is liable to infestation by practically all the major stored grain pests. These are :

1. The Rice weevil. (*Sitophilus oryzae*).
2. The Borer beetle. (*Rhizopertha dominica*).
3. Khapra. (*Trogoderma granaria*).
4. The Red Grain Beetle or the Red Rust Flour Beetle. (*Tribolium castaneum*).
5. The Round headed flour beetle. (*Laetheticus oryzae*).
6. The flat grain beetle. (*Laemophleus minutus*).
7. The Grain Moth. (*Sitotroga cerealella*).
8. The Rice Moth. (*Corcyra cephalonica*).

In addition, sometimes attack by the Fig moth (*Ephestia cautella*) and the Indian meal moth (*Plodia interpunctella*) is also observed. All these pests are fairly well distributed in the country. *Trogoderma granaria*, however, is found in greater abundance in Saurashtra, Rajasthan, P.E.P.S.U., Punjab, Delhi and U.P.

The damage to wheat during a period of one year's storage may result even up to 10 per cent depending on the conditions of storage and the variety of wheat. In bag storage dark dingy godowns, soft variety of wheat may suffer more than 10 per cent damage. In the bulk stores the damage is restricted to the top few inches layer of the grain. Methods of storage of wheat in the households and by the cultivators, trade and Government are described below.

Domestic storage—Grain is stored in earthen pots or in metal bins. Very often, the covers of the containers are not close fitting with the result that rats and insects get an easy access and damage the grain. The containers are hardly cleaned, new grain is mixed with old grain or put in the used containers with the result that it readily gets infested. It is the usual practice with the housewife to expose the grain to sun's heat when insect infestation is observed. This is, undoubtedly, a sound practice; but if the sun is not sufficiently hot, the insects are not killed. In some families, year's requirements are kept in bags. Here the deterioration is greater. The best method of preventing wheat from deterioration in domestic storage is to keep it in tin bins with close fitting covers. If insects are observed it can be fumigated by ethylene dichloride carbon tetrachloride mixture at the rate of 1 oz. for one maund of grain. The liquid should be poured on the grain, the cover closed and edges plastered. After 48 hours the cover should be opened and the fumigant vapours allowed to escape and the grain will be fit for consumption.

Retail shops—Here the grain is generally kept in bags. The bags are huddled in a room in a haphazard manner. The grain for sale is kept in the verandah or front room in bags with open mouths. The grain may also be kept in small containers. As the grain is generally received in an infested condition except that of fresh harvest, the deterioration continues. If the grain is spoilt to an extent that it is unacceptable to the public, it is cleaned. Looking to the condition of these shops which are also used as residence of the dealers, hardly anything can be done to prevent deterioration. The only consoling factor is that small quantities are held at a time.

Cultivators' storage—This can be divided into (i) underground structures such as *Khattis* and *bandas*, (ii) overground structures such as *Dholis, Bharolas* and *Kothas.*

Underground pits and Khattis—These structures are dug in the soil and are flask shaped with narrow neck. Their size is variable and quantities from 200 to 1,000 maunds can be stored in a single pit. A lining of *bhusa* or straw is given both at the bottom and along the sides and the wheat is stored up to the neck and at the top *bhusa* is spread and the mouth is closed with earth. In these structures the wheat keeps well except that the outer layer is damaged due to moisture and is rendered unfit for human consumption. This damaged grain is known as *bhagar*. If the *khattis* can be made damp proof, this defect can be overcome and the grain would remain in sound condition. Wheat kept in *khattis* loses its germinating power.

In North Madhya Pradesh, *banda* system of storage is common. *Banda* is a well-like structure with brick walls and a layer of *bhusa* is spread on the floor. After the wheat is put, *bhusa* is again spread on the top followed by earth arranged in a conical form. The wheat keeps well and retains its germinating power.

Dholis, Bakharis and Bharolas—These are mud structures, circular or rectangular, constructed on raised platform. A lining of *bhusa* or straw is given at the bottom and the wheat is filled and at the top a layer of *bhusa* is again spread followed by mud plaster. Infestation may occur in these structures but is restricted to the top few inches layer of the grain.

Kothas—These are structures in use both by the trade as well as zamindars. They are room-like structures either with mud walls or brick walls with slanting or flat roof. There is, generally, one door and a manhole is provided in the top portion of the wall. Here the wheat is stored in bulk and planks are fitted in the door as a barricade. When the level of the grain reaches the door height, further quantity is introduced through the manhole. The wheat keeps fairly well in these structures, but the top few inches grain is damaged by pests. If the wheat is initially infested, the damage is spread throughout the mass.

The trade, generally, stores grain either in *Kothas* as described above or in bags in rooms with *kutcha* or *pucca* floor and which are dark and dingy. In the latter the damage is considerable both by pests and rats. The trade in U.P., however, has made improvement

by constructing cement concrete *khattis*, $^{2}/_{3}$ portion of which is underground and $^{1}/_{3}$ overground. The capacity is 750 to 1,000 maunds. In these there is no damage due to formation of *bhagar* but insect damage may appear and top few inches layer of the grain spoiled.

Government stores—Government stores are mostly bag storage godowns and there are few bulk storage bins in Delhi, East Punjab and P.E.P.S.U. The bulk storage structures are overground and built either in cement concrete or brick masonry. Wheat is stored in bulk and the damage is restricted to top layer of the grain, if no treatment is given.

The bag storage godowns are made damp proof and rat proof and well ventilated. The grain is, generally, not kept for long periods in Government godowns but in surplus areas the period may be 7 to 8 months. Disinfestation measures are adopted by many State Governments. These consist of disinfestation of empty stores by 4 per cent B.H.C. or 10 per cent D.D.T. or by Gammexane smoke. These insecticides, however, have no effect against *khapra* larvae which are destroyed either by spray of a colloidal form of pyrethrum or by fumigation.

Dunnage is provided on the floor and uniform stacks of bags are built. These stacks are dusted by 4 per cent B.H.C. so as to prevent infestation or to retard the progress of insect multiplication as the crawling insects, on coming into contact with the insecticidal dust, die. This dust, however, is not full proof, and insect infestation may appear. Secondly, if the grain is already infested, the infestation inside the bags is not eliminated by the insecticidal dust.

For destroying the existing infestation, fumigation is done. In godowns or rooms which can be made air-tight, fumigation by ethylene dichloride carbon tetrachloride is carried out. The fumigant is used at the rate of 20 lbs. for 1,000 cu. ft. of space in the case of bag stores and 40 lbs. for 1,000 maunds of grain for bulk stores. In case, however, there is *khapra* infestation the dose of the fumigant is raised to 25 lbs. for 1,000 cu. ft. of space or 50 lbs. for 1,000 maunds of grain.

These methods have become very popular and though introduced in the year 1947, considerable progress has been made. During the year 1950, 9 million bags have been fumigated in Government godowns and 40 million bags received the insecticidal treatment.

Methods practised in Government godowns can be carried to the trade stores. What is required is an organization for the purpose. In the case of trade stores the first necessity, however, is to bring about improvement in their structures. The godowns should have *pucca* damp proof floor; they should be rat proof and well ventilated. In the case of cultivators' stores, structural modifications should only be introduced after trials and economics are worked out. Unless this is done, it is dangerous to interfere with their methods as on the whole they are fairly satisfactory. If, however, organizations are set up for periodical examination of the stocks, it should be possible in many cases to fumigate the grain if it is found infested. In no case should the fumigation operation be entrusted to a layman.

APPENDIX B

Insect Pests of Wheat and Methods of its Storage

1. Some important insect pests of wheat in India are, *Calandra spp.* (*Sund Wali Sursuri*) the rice and granary weevils, *Rhizopertha* (*ghoon*) the lesser grain borer, and *Trogoderma* (*khapra*). *Oryzaephilus* saw toothed grain beetle and *Tribolium* (*Sursuri*) rust red flour beetle, are not normally able to damage sound grain, but may abound in debris produced by the principal pests of grain.

Calandra spp. are about ⅛″ long, dark brown to black with a prominent snout in front of the head. About 250 eggs are laid by each female in little pits drilled in the grain. They pass about five generations in a year.

Rhizopertha is also about ⅛″ long, cylindrical, dark brown or black, with a rough surface. Its head is bent down under the chest, 300-400 eggs are laid by each female among the grains. The worm like young ones hatching from the eggs bore into the grain and live in them. They also pass about five generations in a year.

Khapra is small dark brown oval-shaped beetle, with head, feelers and legs retractile if disturbed. Each female can lay about 100 eggs. They pass 4 or 5 generations in a year. Their attack is usually restricted to about 6-12 inches from the surface of the grain heap. The larvae are provided with ringe of tufts of reddish brown hair on the body.

2. In different parts of India wheat is stored in a variety of ways, depending upon local weather conditions and quantities in stock, etc.

3. *Underground Storage* is in vogue where subsoil water is low. *Khattis*, *Bandar* and *Targhars* are some types of underground pits of varying shapes and sizes, but internally lined with a thick layer of *bhusa* or straw to protect the grain from ground moisture.

4. *Above ground receptacles or bins* also differ widely in shape, size and construction. They may be made of mud, some times mixed with weeds or straw. *Kothis, Bharolis, Bukharis, Puras, Morais, Kup* or *Musaly*, and *Pallas* are some common above ground receptacles. Sometimes *pucca* bins and bamboo bins are also used.

5. On large scale, bagged wheat is stored on *pucca* floor/plinth or dunnage in godowns or under tarpaulin cover.

6. For bulk storage of wheat elevators are the most suitable receptacles. These are huge buildings made of bricks or reinforced cement concrete, and having many chambers or "*Silos*". They are fitted with appliances for cleaning and drying grain, and loading and off loading wagons. Terminal elevators usually have the capacity of 100,000 to 500,000 maunds, and country elevators, a capacity of about 3,000 to